MPA materials matter

February 2008

Newsletter of the Materials Physics and Applications Division

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Dipen Sinha

Problem solver

By Karen Kippen
MPA Materials Matter Editor

The position of "problem solver" is not officially listed on Dipen Sinha's curriculum vitae, but a quick look at his credentials leaves no doubt it's an apt description.

A team leader in the Sensors and Electromechanical Devices Group (MPA-11) of the Materials Physics and Applications Division, Sinha is the recipient of a Popular Science 100 award and three R&D 100 awards for his sensor work—including one for developing the acoustic chemical fill detector, the first instrument to use nonlinear acoustics to identify fill materials in closed containers from a distance. A 1997 and 2005 Los Alamos Distinguished Performance Award Winner, Sinha is also the principal investigator in two crucial national energy security projects between Chevron Corporation and Los Alamos National Laboratory— noninvasive multiphase flow metering and acoustic reservoir imaging.

"Anyone in any field can come up to me with a technical problem and if it is challenging enough and fun enough I want to learn about that new field and solve that problem," said Sinha. "And I believe every problem has a solution. It may be a…difficult solution, but there is a solution."

That attitude has drawn a diverse set of patrons—from medical doctors to geologists—to Sinha's door, a situation he finds invigorating. "When they give me a problem to solve they don't realize they've done me a favor."

Sinha "really does like taking that innovative step," said former MPA-11 group leader Ken Stroh. "He wants to take knowledge that's not been connected before and apply it to something." He's also a bit of a showman when it comes to pitching his ideas, according to Stroh, who described Sinha's demonstrations and home-made movies that illustrate his novel concepts much more effectively than any stack of PowerPoint slides. "Dipen is certainly doing a great deal for (the Laboratory's)

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Dipen Sinha adjusts a fitting on the noninvasive multiphase flow meter in his MPA-11 laboratory. The apparatus, which Sinha developed for Chevron Corporation, simulates the flow of oil and water out of the ground. Below, the flow meter installed by the oil company for testing in Bakersfield, Calif. Sinha can evaluate it remotely from his office in MPA-11.

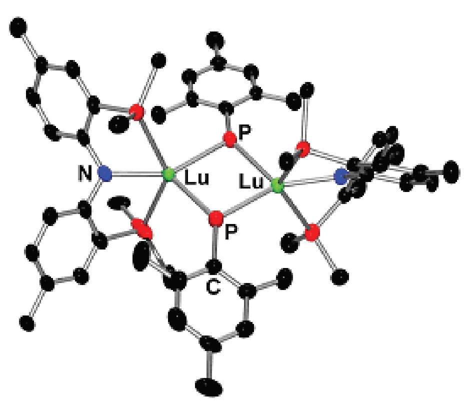
From Alex's desk

Materials Physics and Applications: Scientific strengths on display

By the time you receive this note from the desk, we will have finalized the Division's endorsements to the LDRD–DR process. The MPA Council reviewed 22 LDRD–DR pre-proposals on a windy Tuesday morning. The good thing was we were not outside—except for me during a couple of breaks. The Division endorsed 14 proposals and it was great to see the scientific diversity of the principal investigators in MPA and outside the Division. The competition will be stiff, but we have very strong proposals from our Division.

During the second week of March the American Physical Society (APS) will host its annual meeting in New Orleans. The March Meeting is one of the largest technical meeting organized by the APS, attracting an average 6,000 scientists worldwide. MPA Division will be well represented with five invited talks: "Optical Properties of III-Mn-V Ferromagnetic Semiconductors," by Ken Burch, MPA-CINT; "Imaging the Drift and Diffusion of Optically- and Electrically-injected Spins in Semiconductors," by Scott Crooker, MPA-NHMFL; "Fermi Orbits Versus Fermi Arcs," by Neil Harrison, MPA-NHMFL; "Sliding Charge Density Wave in Manganites," by Susan Cox, MPA-NHMFL; and "The Proposed Big Light Fourth-generation Light Source at the National High Magnetic Field Laboratory," by John Singleton, MPA-NHMFL. The Division will also have several talks and posters.

Science encore, Jaqueline Kiplinger, MPA-10, Brian Scott, MPA-MC, and collaborators have prepared and isolated the first example of a lanthanide metal complex featuring a metal-phosphorus multiple bond (Ln=P), or phosphinidene, functional group. The lutetium phosphinidene complex exists as a dimer and possesses bridging phosphinidene groups (see figure below). Unlike the transition metals and actinides, lanthanide phosphinidenes were an unknown class of compounds until this work. This new class of molecules is anticipated to provide crucial information concerning the nature of and degree of covalency in Ln metal-ligand bonding, which will enhance our ability to develop 4f-5f element separations schemes for advanced nuclear fuel cycle and waste management efforts within the Department of Energy complex. This work appears in the *Journal of the American Chemical Society* **86**, 2408 (2008), the world's leading journal for the publication of important developments in the chemical sciences, and will also be featured in *Chemical & Engineering News.*



X-ray crystal structure of a lutetium phosphinidene dimer complex.

David Morris is the permanent MPA-CINT deputy center leader. David received his PhD in analytical chemistry from North Carolina State University in 1984 and he joins us from C-PCS. David's background and interests will be very beneficial to CINT and the Division. Please join me in welcoming David. Let me also take this opportunity to thank Jeff Willis for his hard work, dedication, and leadership as the acting MPA-CINT deputy center leader for the past five months. Jeff will return to MPA-STC to continue with programmatic work.

Let me end with a safety note. Even though we started the year scientifically and technically very strong we have also had some minor safety incidents: one, a minor electrical shock; and two, a possible minor eye injury. Please be alert and please communicate with your line manager as soon as any incident happens. First and foremost, your line manager will assist you in finding immediate care. Please also make sure to get involved with the IWD (integrated work document) process and make sure you periodically revisit the hazardous associated with lab work and the list of workers authorized in your IWD to perform work.

Finally, make sure to engage with MPA's Worker Safety and Security Team (WSST) members. Any team member would be happy discussing and working with you on any safety

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Findings appear in Science

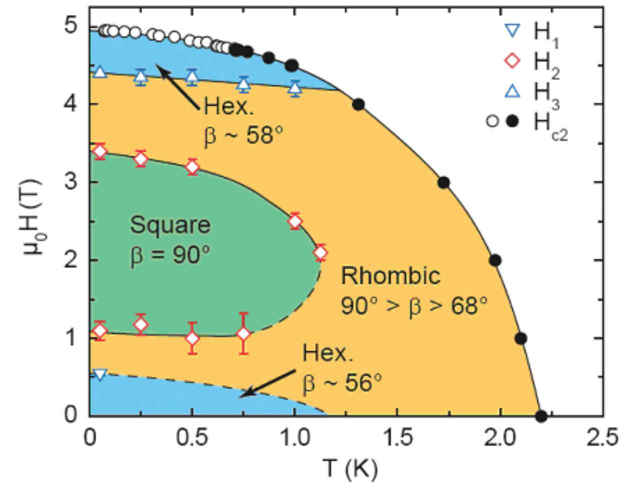
Beyond the Abrikosov-Ginzburg-Landau paradigm: Superconducting vortices in $CeCoIn_5$

An international research team, including members of Los Alamos National Laboratory, has discovered that a magnetic field can interact with the electrons in a superconductor in ways never before observed. Using the Swiss spallation neutron source at the Paul Scherrer Institute in Switzerland, the researchers discovered that when they cooled a single-grain sample of $CeCoIn_5$ to 50mK above absolute zero and applied a magnetic field nearly high enough to entirely suppress superconductivity, they not only observed a regular lattice of quantized supercurrents (so called vortices), but they also found that the core of the vortices contains electronic spins that are partly aligned with the magnetic field. The existence of the observed novel types of vortices is related to the magnetic coupling mechanism that leads to the superconducting condensate in this material—and in many technologically interesting materials such as the high-temperature superconductors.

The findings, published in *Science* 177, **319** (2008), are the first experimental evidence that a theory describing the properties of superconducting vortices and for which Abrikosov and Ginzburg received the Nobel Prize in 2003 does not generally apply in magnetically-induced superconductors and has to be extended to include the field dependence of the quantum correlations of the Cooper pair.

"This discovery has brought physicists one step closer to get to grips with superconductivity at high temperatures," said lead author Prof. Andrea Bianchi of the University of Montreal and former MST-10 postdoctoral researcher. "Until now physicists were going around in circles. This discovery is unambiguous because it was made in a clean superconductor and it is a big boost towards the understanding of unconventional superconductivity." Furthermore, Bianchi explains, "When subjected to intense magnetic fields, these materials produce violently tornado-like twisting columns that grow ever stronger with increasing fields rather than weaken as in all previously investigated materials."

Superconductors hold high promise for technological applications that will change how modern civilization relates to energy storage and transmission—arguably some of the most pressing challenges today. Other notable applications include superconducting digital filters for high-speed communications, more efficient and reliable generators and motors, and superconducting device applications in medical magnetic resonance imaging machines, a technique that is also indispensable for the discovery of new drugs. The first superconductor was discovered nearly a hundred years ago, and in most materials this curious state with no resistance was shown to arise from a phonon-mediated coupling of electrons. However, the present understanding of phonon-mediated superconductors suggests that phonon-mediated mechanisms can never yield superconductivity at high enough temperatures to be useful for device applications. But there is hope: magnetic fluctuations, whose energy can be substantially higher, can also act as electronic glue, leading to high-temperature superconductors that are interesting for applications. The understanding and design of high-temperature superconductors is challenging because all known high-temperature superconductors are complex materials that combine disorder and magnetic and electronic fluctuations that are therefore difficult to model. Materials like $CeCoIn_5$ provide fresh insight because they are clean and relatively simple, magnetically-mediated superconductors where the interactions between superconductivity and magnetism can be studied in a controlled environment.



Structural phase diagram of the vortex lattice in $CeCoIn_5$ with field H || c

"Unconventional superconductivity in $CeCoIn_5$ was discovered here at Los Alamos in 2001. This superficially simple system proved to be a gold mine of phenomena at the frontier of scientific research in solid state physics," said Roman Movshovich of MPA-10. "Several of these issues may have to be tied together to understand the recent small-angle neutron scattering results."

The team consists of Movshovich and Eric. D. Bauer, MPA-10, John L. Sarrao, MPA-DO, and physicists at the University of Montreal, ETH Zurich, Paul Scherrer Institute, University of Notre Dame, University of Birmingham, and Brookhaven National Laboratory. The US Department of Energy, Office of Basic Energy Sciences funded the Los Alamos portion of the work.

Heads UP, MPA!

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Lithium batteries are used daily in our work activities in flashlights, cell phones, cameras, laptop computers, and other devices. For more information about a flashlight containing Lithium batteries that spontaneously combusted, see http://int.lanl.gov/safety/esc/docs/lithium_battery.pdf.

2008 LANL P2 Awards

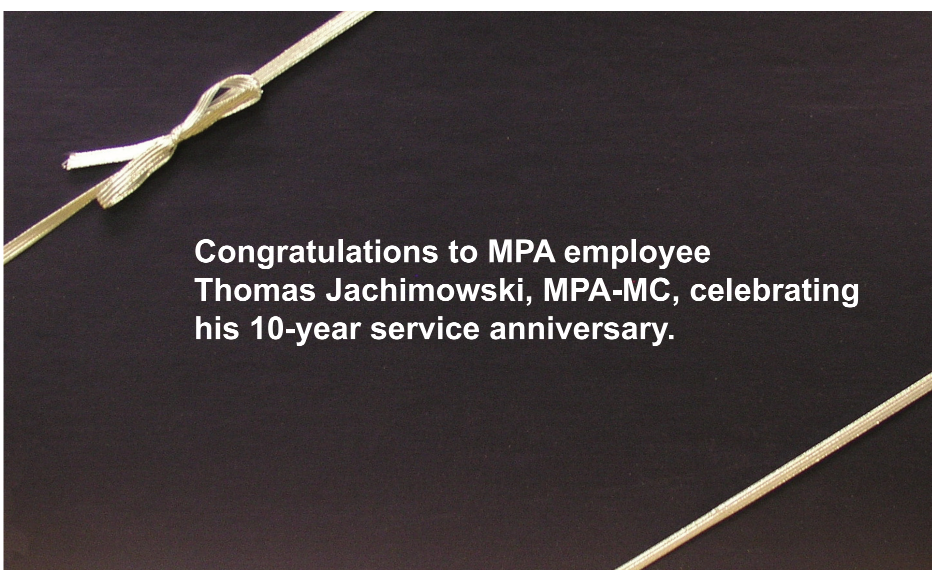
The ENV-Risk Reduction Office Pollution Prevention (P2) Program is soliciting nominations for the 2008 P2 Awards. These cash awards are presented annually to recognize the pollution prevention successes for individuals or teams that have eliminated or minimized waste, air or water pollution; conserved water, electricity or natural gas; procured products with recycled or environmentally preferable content; applied sustainable design elements or projects; used the leadership energy environmental design criteria to design their new facility; or helped in other ways to reduce risk, save money and enhance operations and mission accomplishment through pollution prevention techniques. See http://lanl.gov/environment/risk/lanl_only/p2/awards/nominations.shtml.

Interactions with foreign nationals from or in embargoed countries

A new Security Smart provides guidance for employees whose work requires them to interact with foreign nationals from embargoed countries. See http://int.lanl.gov/security/documents/security-smart/embargoed0208.pdf.

Heads UP, MPA! reports on environment, safety, and health, security, and facility-related news and information.

Celebrating service



CINT's terahertz metamaterials project focus of international conference plenary talks

MPA-CINT's Hou-Tong Chen recently gave two plenary talks on CINT's terahertz metamaterials projects at international conferences.

Last month Chen presented research on electromagnetic metamaterials for terahertz applications at the 2007 Shenzhen International Conference on Advanced Science and Technology—Terahertz Science and Technology, held in Shenzhen, China and sponsored by the Chinese Academy of Sciences and the Shenzhen municipal government.

The conference featured invited speakers in the field of terahertz science and technology from the United States, Germany, Japan, Russia, and China and included discussion of future trends of terahertz science and technology development.

In September Chen presented an invited plenary talk on "Active Metamaterials: a Novel Approach to Manipulate Terahertz Waves" at the Joint 32nd International Conference on Infrared and Millimeter Waves and the 15th International Conference on Terahertz, held in Cardiff, United Kingdom.

The workshop was sponsored by The Institute of Physics, The Institute of Electrical and Electronics Engineers, and Cardiff University.

"Desk" *Continued from page 2*

issues. MPA- WSST members are Chris Sheehan (chair), MPA-STC; Eric Bauer, MPA-10; Roger Lujan, MPA-11; Clay Macomber, MPA-MC; Chuck Mielke, MPA-NHMFL; Darrell Roybal, MPA-NHMFL, and Darrick Williams, MPA-CINT. For more information about MPA-WSST, please visit http://int.lanl.gov/orgs/mpa/mpa_wsst/index.shtml

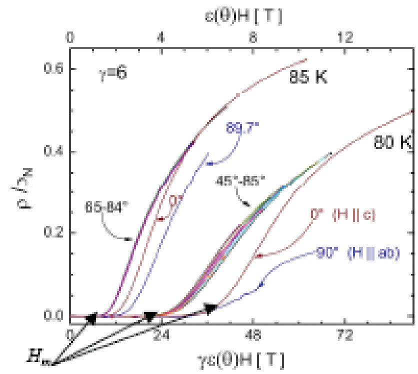
— Interim MPA Division Leader
Alex H. Lacerda

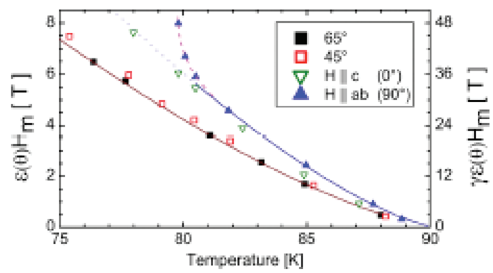
Research resolves longstanding debate, appears in PRL

NHMFL, STC researchers observe smectic vortex phase

Researchers from MPA-STC and MPA-NHMFL are studying the response of vortex matter in high temperature superconductors (HTS) at high magnetic fields. Recently, they were able to resolve a longstanding discussion about the existence of a smectic vortex phase in "low anisotropy" HTS (see figure).

A smectic vortex phase is a liquid-crystalline vortex phase with positional order along one axis and liquid behavior along a perpendicular axis in addition to the orientational order imposed by the anisotropy of the superconductor. In layered superconductors, when a magnetic field (H) is applied along the a-b planes, a smectic vortex phase is expected to cause a rapid increase in the vortex melting field (H_m) at low temperatures. Angular dependent resistivity in fields pulsed to 50 T and critical exponent analysis of the dynamic response of the vortex liquid near H_m confirm the presence of this phase in optimally-doped $YBa_2Cu_3O_7$ films near 80 K (with H > 40T). Also, when H is aligned with the correlated pinning centers (H||ab, or c-axis) H_m increases and vortex motion is reduced with respect to that found at intermediate angles where 3-D anisotropic scaling describes the vortex dynamics up to the highest field measured. This is the first evidence for a smectic phase in optimally doped, high critical current density $YBa_2Cu_3O_7$ films just below 80 K in fields near 50 T.





Left: Normalized resistivity vs. magnetic field scaled with angle using anisotropic scaling at 80 and 85 K. ε(θ) is the electronic mass anisotropy scaling function. Right: Temperature dependence of the melting line at various angles. Solid lines: fits to the data, dotted line: extension of the fit, dashed line: guide to the eye.

The work, "Smectic Vortex Phase in Optimally Doped $YBa_2Cu_3O_7$ Thin Films," by Scott Baily, Boris Maiorov, Honghui Zhou, Steve Foltyn, and Leonardo Civale, MPA-STC; and Fedor Balakirev and Marcelo Jaime, MPA-NHMFL; appears in *Physical Review Letters* **100**, 027004 (2008). The National Science Foundation, DOE, State of Florida, and the NHMFL In-house Research Program funded the research.

"Persistence to high temperatures of interlayer coherence in an organic superconductor," published in *PRL*

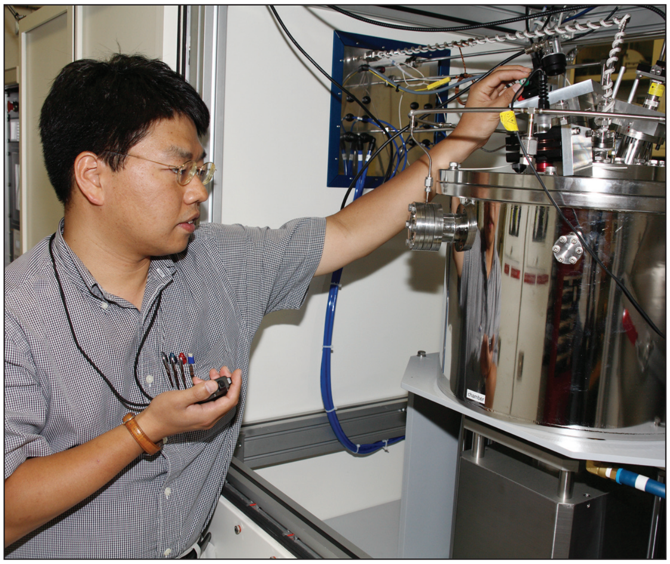
The past two decades have seen a blossoming of interest in compounds with quasi-two-dimensional electronic band structures; examples include layered oxides and crystalline organic metals. These materials may be described by a tight-binding Hamiltonian in which the ratio of the interlayer transfer integral to the average intralayer transfer integral is much less than 1.

The question arises as to whether the interlayer charge transfer is coherent or incoherent in these materials, i.e., whether or not the Fermi surface is three dimensional, extending in the interlayer direction. For example, a widely held view (even quoted in P.W. Anderson's book on cuprate superconductivity) is that a layered material will lose its three dimensionality when the temperature exceeds the interlayer transfer integral. By measuring the magneotresistance of an organic superconductor in fields of up to 45 T, researchers have demonstrated that this view is false; the material retains its three-dimensional electronic properties even when the temperature is some 30 times the interlayer transfer integral. The experiments have also allowed measurement of the electronic scattering rate on different parts of the Fermi surface for the first time. The scattering rate was found to be rather uniform and determined by electron-electron interactions; these observations provide stringent tests for certain models of superconductivity in the organics and cuprates.

The research by John Singleton, Paul Goddard, and Ross McDonald, MPA-NHMFL; A. Ardavan and S.J. Blundell, University of Oxford; A.I. Coldea, Bristol University; S. Tozer, NHMFL, Florida; and J.A. Schlueter, Argonne National Laboratory, was published in *Phys. Rev. Lett.* **99**, 027004 (2007).

The Los Alamos portion of this work was funded by the Laboratory-Directed Research and Development program.

MPA-CINT's Choi receives young scientist award



MPA-CINT postdoctoral researcher Sukgeun Choi received a 2008 Young Scientist Award at the 35th Physics and Chemistry of Semiconductor Interfaces (PCSI) Conference, held recently in Santa Fe. The awards are given to junior scientists including graduate students and postdoctoral researchers to encourage their continuing studies on surface and interface of solid-state materials.

Choi received his BS and MS degrees in physics in 1995 and 1997, respectively, from Kyung Hee University, Seoul, South Korea. In 2006 he received his PhD in materials science and engineering from the University of Minnesota, where he explored the unique growth mechanism of rare-earth group-V compounds on III-V semiconductors in molecular beam epitaxy. He joined Los Alamos National Laboratory in April 2006 and is working on synthesis of semiconductor nanowires under Tom Picraux's supervision. Before coming to the United States he also worked at the Korea Institute of Science and Technology (KIST), Seoul, South Korea as a research associate.

"Sinha" *Continued from page 1*

reputation in industry," Stroh said. "Nothing speaks like success."

Some of Sinha's inventions for Chevron include a solids flow sensor, which noninvasively detects sand in an oil bore; a device for ultrasonic imaging of particulate matter, which may revolutionize the detection of debris in oil pipelines; and in collaboration with Cristian Pantea, an acoustic flashlight that uses sound waves like a light beam to create images of underground.

The atmosphere at Los Alamos, unlike that at a university or a company, allows exposure to so many diverse research areas, said Sinha. "It's one of the joys of working here," he said. Refusing to narrow his focus to any one field, Sinha said, "Life is too short. I have a lot of curiosity and I want to learn as much as possible about as many things. That brings me a lot of joy."

Sinha developed his sense of curiosity and ingenuity early on. Growing up in India, there wasn't a Radio Shack around the corner so even a piece of wire was a hard-gotten prize. Looking up to his older brother who could put together radios and telephones with those cobbled-together bits and pieces "inspired me to no end," he said. "It made me realize you didn't need an expensive lab if you were ingenious. You could do things with very little."

As a result, Sinha likes to come up with simplest, cheapest solution to a problem ("Anyone can find a complicated solution,") and he likes to get answers quickly. "If I feel in my gut that something is working I'll stick to it, but once I decide it's not working I want to get out and go in a different direction."

Sinha, who earned his PhD in physics from Portland State University, came to the Laboratory as postdoctoral researcher in 1980 in what is now MPA-10. "I could hardly wait until 5 a.m. to get up and come to work," he said, describing those early days. He left briefly to work in industry and returned in 1986 to what is now MPA-11.

Always contemplating new challenges Sinha said his new fascination is in how to mimic nature's functionality with modern or newly invented materials. "Real-life problems are so incredibly challenging and fun. They are very, very hard, but they must still be solved because people need solutions. If life depends on it, we will come up with a solution."

Sensors, a water-filled horse trough, and a test station comprise Sinha's acoustic flashlight. The instrument uses sound waves like a light beam to provide images underground. With each deep sea oil well bore costing roughly $160 million these days, the device may provide invaluable information on the strength of a well's integrity.